An Analysis of Meat Income Elasticities by Income Group

by

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Several recent works have found structural change in meat demand (Chavas, Nyankori and Miller, and Braschler). It has been suggested that some of the apparent structural change may be due to changes in the U.S. income distribution (Unnevehr). The marginal propensity to consume meats differs across segments of the income distribution, and therefore changes in this distribution will alter the observed response of average meat consumption to changes in income (Deaton and Muellbauer, p. 156).

In order to capture the full variance in elasticities across income groups, spline functions are used in budget share equations to estimate elasticities for income groups in cross-section household data. These elasticity estimates are used to demonstrate how recent changes in income distribution may have altered the aggregate income response of meat consumption. The estimates also indicate how quickly income growth may lead to saturation in meat consumption.

Model and Data

An individual household (the h^{th} of H households) is assumed to maximize a utility function over the choice of n commodities, subject to the household budget constraint, M. The solution to this optimization problem results in household demand functions for the n commodities:

$$q_{ih} = g_i^h(M^h, p) \quad \text{for} \quad i = 1,2,\ldots,n. \tag{1}$$

The assumption that prices, p, do not vary, a common occurrence in cross-sectional studies, yields the set of household Engel functions:

$$q_{ih} = g_i^h(M^h) \quad \text{for} \quad i = 1,2,\ldots,n. \tag{2}$$

To be consistent with demand theory, the Engel curves must satisfy the adding-up condition. A linear functional form would satisfy this condition, but imposes the restriction that the income elasticity increases with income, which is unreasonable for food items (Phlips, pp. 108-109). Leser proposed an alternative functional form for Engel curves that satisfies the adding-up condition and implies a decline in demand elasticities with rising income. Recently Deaton and Muellbauer noted that Leser's functional form is identical to the form of Engel curves in their Almost Ideal Demand System (Deaton and Muellbauer, p. 75). This form is:

$$W_{ih} = a + b\ (\log M^h) \tag{3}$$

where W_{ih} is the budget share of the ith commodity.

Expenditures vary across households not only due to income levels, but also due to differences in household size and tastes. Incorporating a measure of household size and using sociodemographic variables as indicators of tastes and preferences, equation (3) then becomes:

$$W_{ih} = a + b(\log M^h) + c(\log N) + d(a^h) \quad \text{for} \quad i = 1,2,\ldots,n; \tag{4}$$

where N is some measure of household size, and a^h is a set of sociodemographic factors. To empiricize the model all that remains is to choose a measure of household size and the set of sociodemographic variables. All functions, $b(\cdot)$, $c(\cdot)$, and $d(\cdot)$, are chosen to be linear in parameters.

The data set used in the analysis is the spring round of the 1977-78 U.S. Department of Agriculture Nationwide Household Food Consumption Survey. It contains weekly consumption, expenditure, income, and sociodemographic information from the households surveyed. In this data set approximately one-third of the households surveyed refused to report income. Capps and Cheng (1986), using this survey, employed several methods of replacing these missing observations to obtain expenditure function results for general groups of consumer goods. Their elasticities for "meat and meat alternatives" were identical to the second decimal place for the recommended replacement method and the simple method of dropping the missing observations. The sample selection bias does not appear to be substantial for meats, so the simple method of dropping the missing income data points is used in this paper.

In addition to the missing income observations, some households report no expenditures for particular goods. The period of the survey covered only one week, and many households do not consume particular items during that time frame. Deleting or ignoring reported zero expenditures in empirical analyses may also lead to biases in parameter estimation. If only the non-zero observations on the dependent variable are used in estimation, the conditional expectation of the error term is non-zero. The parameter vector has no component to account for this non-zero conditional mean, thus a "variable" has been omitted and the estimates are biased. Heckman (1976) proposes an estimator to capture this conditional mean. First, the model is run in a probit analysis where the dependent variable equals one if the household reports a positive expenditure and zero if not. From the probit model the inverse Mill's ratio for each household is calculated. This vector is then used as an additional variable in the second stage, the least squares estimation of the model. The parameter on the Mill's ratio variable is a consistent estimate of the conditional mean of the error term. The remaining parameters are consistent and asymptotically normal, and the significance of the coefficient on the Mill's ratio is a test of whether the sample was sufficiently censored to warrant the use of the procedure.

The budget share equations for beef, pork, and chicken were specified in the following linear manner and estimated with Heckman's procedure.

$$\begin{aligned} W_{ih} = {} & B_0 + B_1(SURB_h) + B_2(RUR_h) + B_3(NC_h) + B_4(SO_h) + B_5(WS_h) \\ & + B_6(BLK_h) + B_7(HISP_h) + B_8(OTH_h) + B_9(MLPLEM_h) + B_{10}(HH60_h) \\ & + B_{11}(HH40_h) + B_{12}(MLPLED1_h) + B_{13}(MLPLED2_h) + B_{14}(MILLS_{ih}) \\ & + B_{15}(\log(HHSZ_h)) + \sum_{j=1}^{5} G_j(\log(INC_{jh})) + e_h \end{aligned} \tag{4}$$

Variable names and notation are presented in Table 1. The dependent variables are the budget shares of a particular meat for each household in the sample. The income variable is the weekly before-tax household income. The sociodemographic variables account for household size, population density and geographic region where the household resides, household race, age of the household head, and employment status and education level of the meal planner. Household size was measured in 21-meal equivalents. This number is smaller than actual family size because it has been corrected for meals eaten away from home.[1]

The next to the last term in (4) denotes the splines to be estimated on the income variable. The standard spline formulation is used (Poirier). The first variable in the summation (j=1) is the actual logarithmic transformation of income. The remaining four variables (j=2,3,4,5) represent the functional adjustments at the four nodes which separate the five income groups. The data for these four variables is generated from the

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[1]Instead of using simple measures such as family size (or 21-meal equivalents) for household size, many authors advocate the use of adult equivalent scales based on nutritional requirements of household members (Tedford, Capps and Havlicek, Buse and Salathe, Blokland, and Engel). An adult equivalent scale based on nutritional needs was constructed and found to be highly correlated (rho > 0.93) with household size. Therefore, the simple household size measure was used.

original series in combination with the node information. The data are zeros if the level of the original series is less than the value of the node and, if greater than the node, the data are the original series less the value of the node. Intuitively, the spline function is similar to the use of slope dummies for different income groups. The spline function allows for continuous change between levels, however, rather than discrete change.

The nodes on the spline function were initially set to follow the eight group breakdown used by the U.S. Bureau of the Census in reporting income distribution data. However, the presence of high collinearity (as indicated by measures developed by Belsley, Kuh and Welsh) between three lower and two upper middle income groups led to condensing the eight strata into five. Collinearity suggests behavior within groups is similar, therefore eliminating the need, and making it difficult, to estimate their income responses separately. The five income groups and their population distribution are presented in Table 1.

Deleting the last four spline variables yields, nested within the model in equation (4), the more standard estimated version of a budget share semi-log Engel curve. Formal hypotheses testing can be performed via two methods to compare the spline variable model against the more restrictive non-spline version. The first is to examine the t-statistics on the individual spline variables. The t-statistics, in this case, test if the spline function makes a significant adjustment at the node of the variable considered. If any are significant this suggests rejecting the more restrictive form. The second method is to test the hypothesis that the spline variables j=2,3,4,5, those which allow the function to make adjustments over its range, are zero, i.e., $G_2 = G_3 = G_4 = G_5 = 0$. This is performed via an F-test.

Empirical Results

The income elasticities for beef, pork and chicken are reported in Table 2. Two sets of elasticities are presented for each meat: 1) the least squares regression incorporating the splines of the logarithm of income; and 2) least squares regression using just the logarithm of income. All standard errors were constructed from a heteroskedastic consistent covariance matrix, see White, and all F-tests were based on a Generalized Least Squares formulation. For both model types and all meats, the parameter on the inverse Mill's ratio was significant at the 0.01% level, indicating that the exclusion of zero observations would have biased the results.

The spline regression elasticities are obtained from the formula:

$$\eta_{ij} = \left(\sum_{q=1}^{j} G_q * (1 / W_{ij}) \right) - 1$$

where $j = 1,2,3,4,5$;
i = beef, pork, chicken;
W_{ij} = mean budget share for the i^{th} meat by the j^{th} group.

For the non-spline model, elasticities were calculated using:

$$\eta_{ij} = (G_i * (1 / W_{ij})) - 1$$

where $j = 1,2,3,4,5$;
i = beef, pork, chicken;
W_{ij} = mean budget share for the i^{th} meat by the j^{th} group.

Elasticities from the two different sets of estimates vary widely in magnitude and sign. The semi-log form without splines constrains the elasticities to decline uniformly as income rises, and the income elasticities vary widely from the bottom to the top income groups. The spline estimates vary less widely across groups but also reveal less uniform transitions as income grows. The two functional forms appear to be in closest agreement on the elasticity of the second group but are not very similar elsewhere.

The statistical tests support the spline formulation. The t-statistics of the spline parameters indicate significant differences in parameter estimates among some groups for all meats. Results of the F-tests which examine joint significance of the spline variables j=2,3,4,5, show that this more flexible form is preferred to the more standard form for all meats. These tests suggest rejecting the restrictive model as the true model.

As the spline model does the best job of explaining the data, it is interesting to look at the spline elasticities in more detail. The spline estimates for beef reveal the sharp differences in consumption behavior between the bottom and upper half of the income distribution. For beef, consumption response to income growth is positive for the bottom 45 percent of the distribution, but is less than zero for the middle 33 percent and the upper 8 percent. The upper income groups show saturation in beef consumption.

The elasticities of the spline models for pork and chicken show less change than beef across income groups. In pork, the elasticity is small and positive for the bottom 10 percent, and becomes larger and fairly stable for the remainder of the income groups. Chicken elasticities, likewise, increase as income rises and are very stable across the distribution.

Brevity precludes reporting the sociodemographic dummies, but only a few results stood out as significant. For all three meats, budget shares are smaller in households with a head over 60 years of age. Beef and chicken budget shares are less in rural areas; pork and chicken budget shares are lower among black households.

Table 3 presents average market elasticities, weighted by the proportion of households in each income group in different years. Beef is the least income responsive, pork is next, and chicken is the most income responsive. What is important to this analysis is not the absolute magnitude of the elasticities, but rather how they change over time with the income distribution. Table 3 also presents the median household income as an indicator of how the distribution of real income changed. Economic growth that is widely distributed should result in larger proportions in the upper income categories and lower proportions in the lowest income categories. This is reflected in a rising median income. Recessions or unequally distributed growth will increase the proportion of the population in the lower income groups, and a lower median income will result. A comparison of the median income in 1973 and 1975 shows that the 1973-4 recession made the income distribution "worse". After 1978, macroeconomic policies that were adverse to the formation of higher paying jobs caused the income distribution to become more heavily concentrated in the lower groups. The recovery since 1983 seems to have reversed this trend somewhat.

A comparison of income quantity elasticities in years when the median income reached a turning point reveal how changes in income growth and distribution altered the average propensity to consume meat. The beef income elasticity is negatively related to the median income. In years when income growth or distribution results in higher proportions in the upper income groups, consumption of beef grows less rapidly because these groups have negative income elasticities. Observed average income elasticities for beef should have been lower since 1975, although the simulated elasticity increased slightly between 1978 and 1982. The average propensity to spend income on beef may be declining now, and in 1984 it was already below simulated levels for any previous year.

Pork and chicken income elasticities show the opposite pattern from beef; they increase in years with higher median incomes. Pork consumption is less responsive to changes in the income distribution, however, and the propensity to consume pork declines only slightly when income growth is slow or when the income distribution becomes more heavily weighted in the bottom groups. The chicken elasticities show more variation than pork as income distribution changes and a larger increase in the marginal propensity to consume when income grows and is evenly distributed. Chicken income response should have increased rapidly in the late 1970s economic expansion and then declined from 1978 to 1982.

Conclusions

This paper examined the variation in elasticities across income groups. A spline function that allows for continuous change in elasticities between income groups did a better job of capturing the variation in elasticities across groups than estimation without splines. The differences between the two sets of estimates were substantial, indicating that changes in income response with income growth are not as smooth and uniform as suggested by most traditional functional forms. The spline estimates showed pronounced differences in beef elasticities between the upper and lower halves of the income distribution. The beef elasticity is highest in the lowest income group and deteriorates immediately with increasing income. Pork and chicken, however, show positive elasticities throughout the range of the distribution with slight declines in the highest income group.

The distribution of the U.S. population among real income categories has not followed a steady trend over the last twenty years. Simulated changes in average income elasticities reveal how income growth and distribution may have altered average income response. These simulated elasticities suggest that income response of beef may have declined and chicken may have increased after the mid-1970s, as reported in several studies of structural change in meat demand (Chavas, Hudson and Vertin, Nyankori and Miller). Most studies found inconclusive results regarding change in pork demand, and these results show that income distribution should not alter pork income response as much as the other two meats. While the significance of these results in explaining time-series phenomena has not been tested directly, they do suggest the potential importance of changes in U.S. income distribution for altering the observed aggregate income response.

Table 1. List of Variables Used in the Model

Variate	Variable Name	Description
Budget Share	W	Household budget share for meat
Household Size	HHSZ	21 meal equivalents
Population Density	SURB	Suburban
	RUR	Rural
	URB[a]	Urban
Geographic Region	NC	North Central
	SO	South
	WS	West
	NE[a]	Northeast
Race	BLK	Black
	HISP	Hispanic
	OTH	Other
	WHITE[a]	White
Age of Household Head	HH40	Household head between 40 and 60 years old
	HH60	Household head over 60 years old
	UNDER40[a]	Household head under 40 years old
Employment Status of Meal Planner	MLPLEM	Meal planner is employed
	MLPLUEM[a]	Meal planner is unemployed
Education Level of Meal Planner	MLPLED0[a]	Meal planner less than high school educ.
	MLPLED1	Meal planner has high school degree
	MLPLED2	Meal planner has college degree
Mill's Ratio	MILLS	From probit analysis
Income	INC	Household before tax income

[a] In the constant term.

Distribution of Household Incomes Used to Construct the Spline Nodes.

Group	Income in 1984 Dollars	Percentage of Population in 1978
1	$ 0 - 4,999	9.9
2	$ 5,000 - 19,999	35.1
3	$ 20,000 - 34,999	32.9
4	$ 35,000 - 49,999	14.0
5	over $50,000	8.1

Table 2: Income Elasticities by Household Income Group Estimated from Budget-Share Semi-log Function.

Group	Beef Elasticities		Pork Elasticities		Chicken Elasticities	
	Splines	No Splines*	Splines	No Splines*	Splines	No Splines*
1	0.408*	0.753	0.017*	0.775	0.431*	0.809
2	0.278*#	0.333	0.383*#	0.277	0.393*#	0.495
3	-0.038*#	-0.385	0.154*#	-0.428	0.563*#	-0.125
4	0.605 #	-0.895	0.361*	-1.131	0.882*#	-0.588
5	-0.345*	-1.483	0.302*	-2.023	0.556*	-1.000

* Elasticity is based on a cumulative coefficient which was significantly different from zero.

Parameter estimate is significantly different from previous income group.

Table 3. Simulated Changes in Market Income Elasticities with Changes in the Income Distribution

Year	Median Household Income[a]	Beef	Pork	Chicken
1967	22,222	.182	.262	.534
1973	24,570	.175	.277	.551
1975	22,773	.182	.277	.540
1978	23,984	.176	.279	.547
1982	21,706	.179	.275	.532
1984	22,415	.172	.278	.538

[a] 1984 $.

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